National Center for Excellence in Metalworking Technology
A ManTech Center of Excellence

2004 Annual Report

Advanced Metalworking Solutions

www.ncemt.ctc.com

Operated by

Concurrent Technologies Corporation

For more information, contact:

NCEMT Information Services
Concurrent Technologies Corporation
441Friendship Road, Suite 103
Harrisburg, PA 17111-1204
Phone: 717-565-4405 • Fax: 717-565-4420
e-mail: piastred@ctc.com

This report was prepared by the National Center for Excellence in Metalworking Technology, operated by Concurrent Technologies Corporation *(CTC)*, under Contract No. N00014-00-C-0544 to the Office of Naval Research as part of the Navy ManTech Program. Approved for public release; distribution is unlimited.

Printed on recyclable paper with soy-based ink.

for naval systems that go in harm's way

National Center for Excellence in Metalworking Technology

A ManTech Center of Excellence

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**
4. TITLE AND SUBTITLE **NCEMT 2004 Annual Report. Advanced Metalworking Solutions for naval systems that go in harm's way**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Concurrent Technologies Corporation,NCEMT Information Services,441Friendship Road, Suite 103,Harrisburg,PA,17111-1204**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

As the new Acting Director of the Navy ManTech Program, I look forward to helping ManTech execute its strategy to better align its resources in support of specific weapon systems. Last year, the NCEMT was asked to focus on three critical weapon systems: DD(X), the next generation destroyer; CVN-21, the future aircraft carrier; and J-UCAS, the Joint Unmanned Combat Air System. In his role as new Program Director, Dan Winterscheidt oversaw the project development and execution process to ensure that the NCEMT supported the Naval Integrated Systems Investment Strategy. Under his supervision, the NCEMT developed a sound technical approach and detailed plan for each project by partnering with the appropriate organizations to execute the projects, and provided the exceptional technical and project management support required to deliver advanced metalworking solutions to these key weapon systems.

The NCEMT is helping ManTech achieve its goals through the practical application of innovative metalworking technologies. In this annual report, you will read about the NCEMT's success in developing and deploying advanced manufacturing solutions—metalworking technologies that incorporate materials with high-strength and good corrosion properties, reduce ship weight and lower the center of gravity, eliminate environmental hazards, and utilize advanced bonding methods to meet demanding weapon system requirements.

As the focal point for the Navy's advanced metalworking solutions and manufacturing processes, the NCEMT is the conduit between the development and the implementation of advanced metalworking technology in naval weapon systems. The people of the NCEMT are diligent in their responsiveness to the changing needs of the Navy and in their commitment to providing unprecedented technology for our country's warfighters. I am confident of their ability to apply innovative, reliable metalworking solutions to better serve the weapon system program offices.

Sincerely,

John Carney
Acting Director
Navy Manufacturing Technology Program
Office of Naval Research

"The best method of overcoming obstacles is the team method." During my first year as NCEMT Program Director, we have followed the guidance of well-known Army General Colin Powell and have built strong project teams to address the challenges presented in the development of key naval weapons systems.

The U.S. Navy is the most powerful naval force that has ever sailed the oceans, and during times of war, global terrorism and international conflict, the need for the NCEMT to work in tandem with government and industry to provide better metalworking solutions takes on greater significance. In FY04, we continued our very successful projects in support of Navy and Marine Corps program offices, and were asked to focus our resources on the materials and manufacturing needs of three strategic weapon systems: the next-generation surface combatant DD(X), the 21st Century carrier CVN-21, and the joint unmanned aircraft J-UCAS.

Last year, our new startup efforts concentrated primarily on CVN-21. Working closely with the Future Aircraft Carriers Program Office (PMS 378), NAVSEA, Carderock, Northrop Grumman Newport News, and other industry participants, the NCEMT used a team approach to successfully develop and initiate six new projects in support of this critical new weapon system. The first three projects focus on the application of high strength-to-weight-ratio materials (10Ni Steel, LASCOR, and titanium) to reduce ship weight and lower the center of gravity, whereas the other tasks have been designed to implement necessary welding enhancements.

Working closely with the Navy Joining Center, Northrop Grumman Ship Systems, Bath Iron Works, and other integrated project team members, the NCEMT is enhancing DD(X) by ensuring that complex, curved steel plates are formed accurately and efficiently, that high-productivity welding technology results in greater survivability for large thick-section, high-strength steel structures, and that other manufacturing and ship performance issues are addressed.

For the Joint Unmanned Combat Air System (J-UCAS), the NCEMT is working with Boeing and Northrop Grumman to identify state-of-the-art metalworking technologies that will contribute to operational performance while reducing the cost of the aircraft.

This annual report details some of the alliances and advances the NCEMT has made to develop better metalworking solutions for aircraft carriers, surface ships, submarines, aircraft, and Marine Corps weapon systems. You will also read about the significant projects we are performing that are funded by other DoD organizations, such as our Combat Vehicle materials and manufacturing development work for TARDEC.

Naval and amphibious forces continue to serve as the foundation of our country's ability to project power overseas, and the 21st Century will see increasingly greater impetus dedicated to developing more multi-mission-capable platforms.

I look forward to leading the NCEMT in its mission to support the advanced manufacturing and technological challenges of these new naval weapon systems and continuing our steadfast belief in partnership. I congratulate John Carney on his assignment as the new Acting Director of the ManTech Program, and hope to further the NCEMT's success under his guidance.

The legacy of the NCEMT resides in its ability to solve metalworking issues. Today, more than ever before, we are committed to teamwork and to developing advanced metalworking solutions that enhance lethality, agility, and survivability as the Navy goes in harm's way.

Daniel L. Winterscheidt, Ph.D.
Program Director
National Center for Excellence in Metalworking Technology

Ships and Submarines

Survivability and reliability—paramount to the vessels of the U.S. fleet—begin with solid planning, design and manufacturing processes and procedures. The NCEMT works closely with its military and industry partners to identify the needs of each project and actively contribute to Integrated Project Teams (IPTs) that are responsive, client-focused and goal-oriented.

To meet the need for innovative manufacturing approaches for ship hulls, the NCEMT is working with the DD(X) design agent Northrop Grumman Ship Systems to undertake projects prioritized by the Strike Surface Affordability Initiative Leadership IPT. DD(X) is the centerpiece of the U.S. Navy's new family of surface combatants, and the NCEMT is leading the development of a prototype Automated Thermal Plate Forming (ATPF) system for hull applications. This is one of three DD(X) - related projects for which the NCEMT has been tasked.

Ships and Submarines

Leading a DD(X) Project Team

The ATPF project, developed in conjunction with the Navy Joining Center (NJC), is working to meet shipyards' needs to accurately form steel plate corresponding to the unique hull geometry of the DD(X) design. Technology developed for this project has the potential to increase throughput by 100 percent, reduce rework by 80 percent, and decrease direct labor costs by 50 percent for the DD(X) hull. In addition, the technology may be transferable to other ship programs.

A high priority for the DD(X) ManTech Program, the ATPF project seeks to reduce the amount of manual forming and reproducibility currently required to manufacture complex hull curvatures. The NCEMT will construct a prototype ATPF system as well as technical specifications for a full-size ATPF system that can process plates within a 12-foot wide by 56-foot long by 5-foot high working envelope—a system capable of operating in a harsh shipyard production environment.

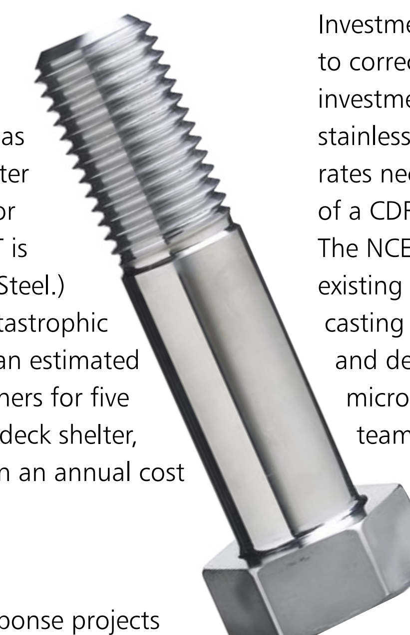
Partnering to Enhance DD(X) Technologies

Working with the Naval Surface Warfare Center – Carderock Division, the NJC, Northrop Grumman and Bath Iron Works, the NCEMT has begun to develop advanced bonding methods for steel structures. DD(X) requires application of Special Hull Treatment (SHT), a demanding and expensive process. Significant savings can be realized by optimizing paints, adhesives, tiles and enclosures for the DD(X) application. Even greater savings could be realized by successful development of a spray-on treatment, which is also under investigation. The results of this project could potentially be leveraged to other combatant platforms.

The NCEMT is also working on a project to implement high-productivity welding processes for large, thick-section, high-strength steel structures with enhanced survivability for DD(X). The anticipated benefits of this new project: a 14,400-hour reduction in weld labor per ship, diminished weld distortion and improved weld quality, which will decrease fabrication costs and improve cycle times. The new technology is expected to be implemented upon initial fabrication of DD(X), which is scheduled for 2006.

Conceptual design of DD(X), the next-generation surface combatant.

Improving Marine-Grade Fasteners



Also in 2006, new NCEMT-developed high-strength marine grade fasteners will be implemented aboard Virginia-class submarines. Working with its industry partners, the NCEMT has developed process parameters for manufacturing large-diameter steel alloy MP-98T fasteners that achieve Navy requirements for added strength, corrosion resistance and toughness. (MP-98T is a multiphase cobalt-based alloy produced by Timken Latrobe Steel.) Bolts that once had to be changed periodically to preclude catastrophic failure will soon be used for the life of the submarine, saving an estimated $220,000 per year per subsystem. Plans to use the new fasteners for five subsystems (the propulsor, advanced seal delivery system, dry deck shelter, high frequency sail array, and wide aperture array) will result in an annual cost avoidance of $1.1 million per fielded submarine.

Completing Rapid Response Projects

During the past year, the NCEMT was awarded two Rapid Response projects relating to the Virginia-class submarine.

The first project, *Sand Cast Mold Drying,* will provide assurance that mold-drying procedures are corrected so that the next Virginia-class rotor cast will be successful. The Naval Sea Systems Command (NAVSEA) requested that the NCEMT participate in the Critical Design Review (CDR) Team that was organized to address the situation after the latest rotor had significant casting defects. Procedures under development at the NCEMT are expected to reduce the moisture level in the sand mold cavity, which should eliminate the worm hole porosity defects that were observed. The weapon system delivery schedule depends on the successful re-manufacture of this casting.

The second project, Stainless Steel Investment Castings, is expected to correct problems relating to an investment casting process for 17-4 stainless steel. Recent high defect rates necessitated the organization of a CDR team for rapid response. The NCEMT plans to analyze the existing component defects, provide casting process simulation support, and define a process to reduce micro-porosity defects. The CDR team organizations include the Naval Surface Warfare Center – Carderock Division, NAVSEA, Electric Boat, the NCEMT, and the industrial manufacturer, Tech Cast, Inc.

Rapid Response projects are critical to the ManTech mission. The NCEMT has demonstrated agility and reliability when asked to address pressing, unplanned manufacturing issues in a compressed timeframe.

Aircraft Carriers

Aircraft carriers—the centerpiece of the U.S. Navy's forward presence—are the cornerstone of maritime expeditionary forces in times of conflict. Today's *Nimitz*-class carriers, the largest warships in the world, are scheduled for replacement, and the NCEMT is working with many organizations as part of Integrated Project Teams (IPTs) to accomplish project goals associated with the development of the Navy's future aircraft carrier, CVN-21.

The NCEMT is providing metalworking and manufacturing expertise for several projects pertaining to the development of CVN-21, the Navy's future aircraft carrier.

Northrop Grumman Newport News, CVN-21 designer and manufacturer, is leading the effort to develop and insert new technology. The NCEMT performed a Concept Exploration Project to determine where ManTech may best benefit the CVN-21 program, and several project concepts for potential future support were identified. These project concepts include a fire-resistant door, friction stir welding applications, one-sided welding, thick-section HSLA-65 welding, cold/hot forming limits for HSLA-65 and flame straightening. Following the Concept Exploration Project, the NCEMT was tasked to provide metalworking and manufacturing expertise for the following projects.

Enhancing LASCOR Technology

Current weight and center-of-gravity projections for CVN-21 exceed established goals. To optimize ship stability and enable the carrier to maintain its intended warfighting capabilities, the implementation of stiff, lightweight, metallic-sandwich panels over standard plate and stiffener-type structures can reduce weight while meeting or exceeding stiffness and strength requirements for shipboard applications.

These stiff, lightweight, metallic-sandwich panels are known as LASCOR (LASer-welded corrugated-CORe) panels. The LASCOR IPT—consisting of the NCEMT, the Institute for Manufacturing and Sustainment Technologies (iMAST), the Navy Joining Center (NJC), NAVSEA, the Naval Surface Warfare Center – Carderock Division (NSWCCD), Northrop Grumman Newport News and Applied Thermal Sciences—is evaluating the viability of LASCOR technology and its potential for CVN-21 applications. This LASCOR project benefits from the last 20 years of research, development and testing performed by iMAST and NSWCCD.

Manufacturing methods must be developed if LASCOR is to be used in critical applications. Currently, there are insufficient design requirements and fabrication experience relating to the use of LASCOR panels in critical applications. In addition, methods of attaching LASCOR panels to the ship structure, methods of accounting for the directional properties of the panels, and repair issues have yet to be established. The IPT has begun work to demonstrate the viability and shipyard use of LASCOR technology. Engineers are addressing issues such as joint attachment, stud application, reparability, application development and demonstration.

If LASCOR technology proves to be a viable solution, a 15–40 percent weight savings could be obtained. For example, if LASCOR is used for decking applications over traditional plate and stiffener combinations, then approximately 20 percent weight savings can be obtained, while meeting or exceeding load requirements. Other potential benefits involved in using LASCOR include reduced life-cycle maintenance costs and increased ship compartment useable volume.

Identifying Cost-Effective Titanium Components

Another project aimed at decreasing the weight of CVN-21 involves the identification, development, evaluation and demonstration of suitable manufacturing techniques for titanium naval components. NAVSEA, Northrop Grumman Newport News, NSWCCD and NJC are working with the NCEMT on this project.

Titanium exhibits high specific strength, high fatigue strength, good corrosion, reduced magnetic signature and good fracture toughness properties. Although it is an attractive material for naval applications, until recently titanium's use has been limited because of high costs.

Leveraging its past achievements in developing and refining titanium fabrication techniques, the NCEMT and its partners are now working to identify cost-effective titanium candidate components for CVN-21. Future phases of the project involve manufacturing and evaluating the demonstration component(s) that were identified and testing the new titanium components at Northrop Grumman Newport News.

Optimizing High-Strength, Reduced-Weight Steel

Research on 10-percent Nickel (10Ni) steel began as early as 1995 and was built on knowledge and research of the Ni-Cr-Mo-V Navy steels from HY-130 through HY-180 (10Ni-8Co-2Cr-1Mo). This research

Aircraft Carriers

was able to be utlized when the CVN-21 program had a need to reduce weight and renewed interest in a tough, weldable steel system alloy with strength greater than HSLA-211. This need transitioned to the Metallic Materials Advanced Development and Certification Program (MMADCP) where high-strength, high-toughness lab heat materials were procured and tested. Many years of research and development have determined that 10Ni steel has the potential to provide improved strength and toughness while maintaining or exceeding critical performance requirements at reduced weight. Because this steel has low carbon content and clean melt practices, it may also be easily weldable.

The 10Ni steel project consists of a well-rounded IPT that includes the NCEMT, NSWCCD, the NJC, NAVSEA, International Steel Group and Northrop Grumman Newport News. Metallurgists are working to determine the optimum processing conditions necessary to meet mechanical property requirements. The objective is to optimize the heat treatment process and evaluate material, ballistic, explosion, mechanical, structural, welding and corrosion properties from slab ingot rolled plate through procurement and evaluation of production steel. If the 10Ni material retains or exceeds material performance levels relative to the steel currently in use, the thickness of the steel plating can be reduced to lower the weight per application.

Decreasing Weld Distortion

Because the CVN-21 class of aircraft carriers will use different grades and gages of steel than prior carriers, new fabrication parameters must be established to achieve flatness requirements in foundation assemblies.

The NCEMT is working with Northrop Grumman Newport News to develop, calibrate, upgrade and validate fabrication parameters that will produce inner-bottom assemblies that meet flatness requirements. To accomplish this, the NCEMT and Northrop Grumman Newport News will predict the expected weld distortion, define an initial camber design for a typical inner-bottom assembly, and then manufacture the intended assembly while measuring any distortion that occurs during fabrication. Results of this evaluation will be used to define the camber and assembly practices to be used for actual ship production.

Developing a Low-Manganese Welding Electrode

The NCEMT is part of an IPT working on a project that is expected to reduce welder exposure to manganese fumes and increase ship welders' productivity by eliminating the need to wear respirators. IPT members include Northrop Grumman Newport News, NSWCCD, ESAB, Hobart Brothers Company and the NCEMT.

The team is developing a modified MIL-101T-"X" low-fuming, flux-core welding electrode for use with 95% Ar-5% CO_2 or 75% Ar-25% CO_2 shielding gas. The modified electrode will minimize welder exposure to manganese and other fumes without increasing porosity or diffusible hydrogen content, while still meeting NAVSEA requirements and shipyard usability characteristics.

The new MIL-101T-"X" flux core welding electrode is expected to be used extensively by all surface shipyards for joining HSLA-80 and 100 high-strength steels. Therefore, the new technology will have applications not only for CVN-21, but DD(X) and other ships.

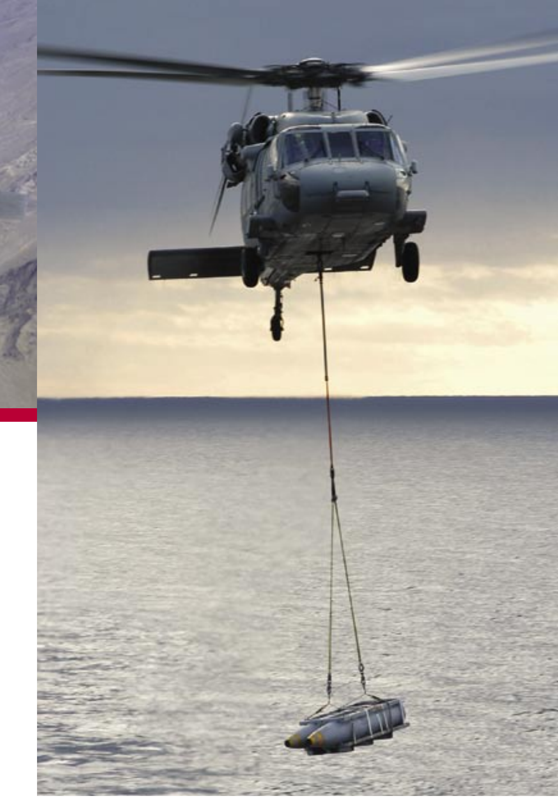
Improving Availability of SMAW Electrodes

On CVN-21, the MIL-10718-M electrode must be used for all shielded metal arc welding (SMAW) of HSLA-100 and HY-100 steels in order to meet the required ballistic performance. However, the electrode is only available in a 1/8-inch diameter size, which has a history of unacceptable rejection rates during conformance and/or in-house verification testing at Northrop Grumman Newport News. After extensive study on rejection causes, NAVSEA revised purchase specifications. Verification lots are now needed to assure Northrop Grumman Newport News and electrode manufacturers that problems with the manufacturing processes and testing methods have been corrected.

The NCEMT is a member of an IPT that will optimize 1/8-inch diameter and develop 3/32-inch diameter MIL-10718-M SMAW electrodes during phase one of a new project to improve the reliability and availability of SMAW electrodes. In phase two, the team will develop 5/32-inch diameter MIL-10718-M SMAW electrodes. The NCEMT is joined in this effort by IPT members Northrop Grumman Newport News, General Dynamics Electric Boat, NSWCCD, ESAB and Lincoln Electric.

This project will ensure the consistent availability of several diameters of MIL-10718-M electrodes necessary for the cost-effective production of the CVN-21 class of aircraft carriers, Virginia-Class submarines, and LHA-R. These electrodes will provide welds capable of meeting ballistic requirements in addition to important cost and performance benefits.

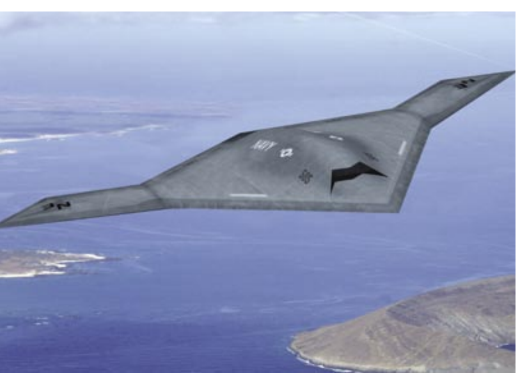


Aircraft

Aircraft

From the first propeller-driven fighters to today's sophisticated Unmanned Air Vehicles (UAVs), U.S. military aircraft have attained a superior balance of stealth, endurance and firepower, and advanced metalworking technologies have a role in maintaining that level of superiority.



Northrop Grumman built the X-47A air vehicle to demonstrate the technical feasibility of the J-UCAS concept. The Boeing Company's X-45C J-UCAS concept drawing is pictured on page 9, left.

During the past fiscal year, the NCEMT completed a Concept Exploration Project that identified promising metalworking technologies of significant interest to the industrial systems integrators of the Joint-Unmanned Combat Air System (J-UCAS). The J-UCAS air vehicle is still in development by competing teams from The Boeing Company and Northrop Grumman. The NCEMT conducted the Concept Exploration Project in close cooperation and coordination with the J-UCAS Program Office, the Naval Air Systems Command and the two contractors to ensure timely information exchange and to facilitate transition and implementation of results. The NCEMT will continue to work with the Navy and both airframe companies to further manufacturing technologies for use in the Navy variant of the J-UCAS.

Manufacturing Titanium Metal Matrix Composites

The NCEMT and its partners have completed a project that examined the use of titanium metal matrix composites (TMCs) for rotating components for use in the F136 engine for the F-35 Fighter aircraft. TMCs are highly durable—offering significantly improved life-cycle costs if manufacturing processes can be made more affordable and critical design data can be developed.

The NCEMT developed a comprehensive new modeling approach to simulate the electron beam physical vapor disposition of Ti-6-Al-4V onto silicon carbide (SiC) fibers. The approach is based on the numerical solution of evaporation, fluid flow, species transfer, heat transfer and a deposition/condensation model. An analytical method that can be used to construct a life-prediction model for TMC rotating components was also developed.

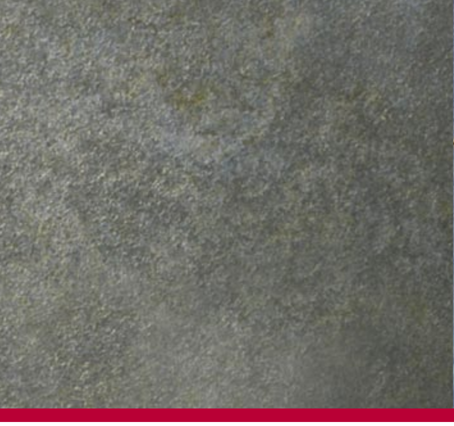
Reduced Buy-to-Fly Manufacturing Process Development

The Joint Strike Fighter Integrally Bladed Rotor (IBR) disks, manufactured from Ti-6242S alloy with integral arms and flanges for mounting, have a high buy-to-fly ratio (measured as the initial raw material input eight divided by the finish machined part weight). The *Reduced Buy-to-Fly Aerospace Disk Components Project* was designed to develop a low buy-to-fly strategy that consisted of forging disks and IBRs to aggressive, nearer net-shape, forge-over-finish designs and identifying a flowforming material for the integral arms and flanges. It was intended that this project also further the development of Contour Following Ultrasonic Testing (CFUT) for Ti-6242S, which would result in a significant cost reduction.

The NCEMT worked with Pratt & Whitney and Ultra Tech Machinery to define process requirements and numerical process modeling evaluations for flowform manufacturing Ti-6242S. In-process tooling conceptual designs and a thorough metallurgical evaluation of the component alloy (Ti-6242S) were also completed. There were sufficient data from the metallurgical evaluations and the numerical process modeling to indicate that the flowforming of Ti-6242S alloy would be successful at elevated temperatures to produce a reduced buy-to-fly, reduced-cost forging. Results of these efforts are documented in a report that is available for future reference throughout the industry.

Redesigning Dynamic Components

The NCEMT is working closely with PMA 299 Program Office and Sikorsky Aircraft Corporation to evaluate methods of improving the H-60 helicopter's dynamic component's service life. The project, which was initiated following a review by the Naval Air System Command's MH-60R Air Vehicle Systems Team, is designed to study selected dynamic components, focusing on corrosion, wear, maintenance damage and review of aircraft maintenance processes and procedures. In addition, the project team has been tasked to assess and submit recommendations to improve the manufacturing, production installation, and maintenance installation and removal of the MH-60R Sonobuoy Launcher assembly.

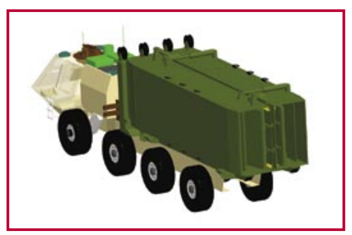
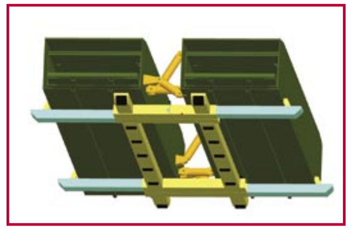
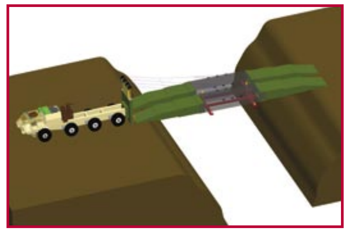


The team has outlined many recommendations for dynamic component service life improvements. Some of the most promising and cost-effective recommendations involve developing and qualifying repairs to the main support bridge; refining the design of two new specialty tools that will prevent damage to the bridge and adjacent components during maintenance; applying alternate sealants and coatings to prevent or reduce corrosion; and applying design and material changes to improve maintenance installation tolerances and ensure crash-worthiness to the existing sonobuoy launcher assembly.

The NCEMT is engaged in these and dozens of other projects to develop advanced metalworking solutions. Together with our military and industry partners, the NCEMT is enabling the cost-effective production of superior aircraft, developing new ways to lower acquisition and life-cycle expenses, and helping to ensure defense readiness.




Ground Weapon Systems

Diagrams depict the transport and assembly of the Advanced Metallic Army Bridge, which is in the design phase. Two soldiers must be capable of deploying or recovering the telescoping bridge in 10 minutes.

Designing a Telescoping Bridge

The Advanced Metallic Army Bridge project is one example of the NCEMT's responsiveness to change and ability to leverage proven technologies. The U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) tasked the NCEMT to develop two novel assault bridge designs. Two soldiers must be capable of deploying or recovering the mechanized bridge within 10 minutes. The bridge must weigh less than 26,000 pounds and meet a number of other stringent requirements. The NCEMT innovated and completed two designs, then selected the telescopic bridge design, further adapting and developing the design to meet Army needs when the project was up-sized to support significantly increased weight. (Weight specifications increased from Military Load Classification [MLC] 30 to MLC 65.)

The bridge design employs advanced structural materials and manufacturing techniques that were developed under the TARDEC-sponsored Combat Vehicle Research program. Computer-Aided Design and Engineering and finite element analyses determined that extrusions of advanced aluminum alloys such as 7055 and 2094 are more weight efficient than steel alloys and/or aluminum alloys such as 6061 or 5083. In addition, low-cost titanium alloys are particularly useful for high-wear and corrosion-prone areas such as pins, fasteners and joints. Friction stir welding is baselined for advance aluminum alloy joints because it produces robust joints where gas metal arc welding is not an option for structural areas. With TARDEC support, the NCEMT stands ready to refine and develop the telescopic advanced metallic bridge to the demonstration level.

Improving Costs and Processes for New Howitzer

The NCEMT has been an active participant in the development of innovative manufacturing approaches for the M777 Lightweight 155mm Howitzer (LW155), a titanium-intensive weapon that will be used by both the Marine Corps and Army. Working with the Joint Program Management Office, BAE Systems and industry partners, the NCEMT identified near-net shape titanium casting technology as a preferred technology to reduce weld lineage, part count, manufacturing waste, and manufacturing costs. In addition, flowforming, which refines microstructure and improves properties, was demonstrated for fabricating the cradle tube in the recoil system.

The manufacturing cost of the spade was decreased by converting a fabricated 60-piece component into a single-piece investment casting. A three-piece saddle component that was previously produced with several welding and machining steps was converted to a single piece investment casting as well, eliminating several manufacturing and inspection steps. Another inherently expensive component, the cradle tube, was initially produced by extruding into thick tube and machining the tube down to the required wall thickness. By using flowforming, a near-net shape forming process, the tube can now be manufactured with far less machining waste. The new manufacturing approaches developed under this project will offer substantial cost savings to the program.

To reduce the cost of Ti-6Al-4V alloy ingots by improving the ingot surface finish, the NCEMT optimized the single-melt (SM) plasma arc cold hearth melting (PAM) process. The NCEMT demonstrated an improved SM PAM ingot finish of sufficient quality that no surface machining will be required prior to forging. As a result, the baseline properties of SM PAM versus double vacuum-arc remelted Ti-6-4 alloy were established, and forged bell housings made using SM PAM Ti-6-4 alloy up to 0.24% wt. oxygen are now viable for LW155 use and for other Marine Corps applications.

Making Low-Cost Titanium Work

Considerable progress is being made in the use of titanium, which exhibits exceptionally high specific strength and excellent corrosion resistance. The NCEMT is working with the Armament Research Development and Engineering Center (ARDEC) to develop and demonstrate low-cost titanium SM PAM process casting and fabrication technologies for U.S. Army applications produced by rolling, extrusion and superplastic forming. The goal of this effort is to achieve significant cost reductions in the processing of titanium. The basic approach in this work is to eliminate intermediate manufacturing steps by utilizing the SM PAM process and to allow low-cost, high-oxygen scrap to be used. The work has demonstrated that the SM titanium alloy is suitable for a variety of weaponry at a savings of up to 40 percent.

Transferring Promising Technologies

In response to the mandate to reduce combat vehicle weight while ensuring survivability, maintainability and life-cycle cost-effectiveness, the NCEMT has defined an aggressive plan to transfer the following promising technologies to the combat vehicle community: high-strength aluminum-lithium and low-cost titanium alloys; novel friction stir welding technology; and

Ground Weapon Systems

combinations of advanced metallics, ceramics and polymers for improved, weight-efficient armor.

Over the past several years, the NCEMT has been effecting the technology transfer of friction stir welding to large, complex structures with high joint strength and ductility. Progress in friction stir welding techniques has led to numerous advantages over conventional fusion welding. In addition to superior strength and ductility, these advantages include significant reduction in residual stresses, elimination of filler wire, greatly simplified weld preparation procedures, and reduced environmental health and safety concerns.

The NCEMT is working closely with TARDEC, combat vehicle manufacturers, key materials suppliers and processing-technology providers to define lightweight demonstration structures that are properly sized to specific combat vehicles. These structures will be fabricated and evaluated with assistance from TARDEC and the prime vehicle manufacturers to rapidly effect technology transfer.

The NCEMT is a member of a team that is facilitating the integration of an active suspension system into the Lancer Combat Vehicle, a concept demonstrator for Future Combat Systems.

Meeting Diverse Needs Through Team Effort

The NCEMT is proud to be engaged in a number of high-priority projects that serve the needs of America's warfighters and support the U.S. industrial base. The success of the *Integration Design and Hardware Fabrication in Support of Active Suspension Demonstrations Project* is one more example of the teamwork necessary to achieve broad-based goals. In this project, the NCEMT worked together with TARDEC, United Defense LP, University of Texas Center for Electromechanics and Northrop Grumman. The team facilitated the design, manufacture and implementation of the road arms that will be used on the active suspension system of the Lancer Combat Vehicle, a concept demonstrator for Future Combat Systems.

Through continued team efforts, innovative new processes and applications such as those profiled here, the NCEMT will meet the rapid deployment requirements of today's ground vehicle systems as well as those of the future force.

Photo Credits

Front Cover
Guided missile cruiser USS Vincennes.
U.S. Navy photo by Lt. Chuck Bell

USS George Washington. U.S. Navy photo by Photographer's Mate 3rd Class Heather Hess

Surface-to-air missile launched from USS George Philip. U.S. Navy photo by Photographer's Mate 2nd Class Kenneth Pace

Nuclear powered sub, USS Albany.
U.S. Navy photo by Photographer's Mate 2nd Class Steven J. Weber

Page 1
The nation's first nuclear-powered sub PCU Virginia. U.S. Navy photo by Journalist 2nd Class Christina M. Shaw

USS Vincennes. U.S. Navy photo

Page 2
Guided missile destroyer USS Howard.
U.S. Navy photo by Photographer's Mate Airman Richard R. Wait

Conceptual design of DD(X). Northrop Grumman photo

Page 3
PCU Virginia. U.S. Navy photo by General Dynamics Electric Boat

Nuclear powered attack submarine Virginia while under construction. U.S. Navy photo

(middle) High-strength, marine-grade fastener.
Cramer Studio, Inc.

Page 4
Aboard the USS Enterprise (CVN 65).
U.S. Navy photo by Photographer's Mate Airman Milosz Reterski

CVN-21 warship. Northrop Grumman photo

Page 5
Nimitz-class aircraft carrier USS John C. Stennis.
U.S. Navy photo by Photographer's Mate Airman Randi R. Brown

USS Enterprise, the first nuclear powered aircraft carrier. Northrop Grumman photo

Page 6
Lower box unit of the aircraft carrier Ronald Reagan is lowered into place.
Northrop Grumman photo

Aircraft carriers USS Kitty Hawk and USS John C. Stennis. U.S. Navy photo by Photographer's Mate 2nd Class William H. Ramsey

Page 7
Flight deck of USS Kitty Hawk. U.S. Navy photo by Photographer's Mate Airman Bo J. Flannigan

Page 8
An F-14 prepares to land on deck of USS George Washington. U.S. Navy photo by Photographer's Mate Airman Rex Nelson

X-47A J-UCAS air vehicle. Northrop Grumman

Page 9
X-45C J-UCAS concept drawing.
The Boeing Company

Joint Strike Fighter. Lockheed Martin photo

MH-60S helicopter transfers ordnance.
U.S. Navy photo by Photographer's Mate Airman Konstandinos Goumenidis

Page 10
LW 155 Howitzer. USMC photo

Mine-blast structure. *CTC* photo

Page 11
Firing round from a Howitzer. U.S. Navy photo by Photographer's Mate 1st Class Jane West

Loading the Howitzer. U.S. Navy photo by Photographer's Mate 1st Class Jane West

Spade for M777 Lightweight 155mm Howitzer.
CTC photo

Page 12
M777 Lightweight 155mm Howitzer.
BAE Systems photo

Advanced Amphibious Assault Vehicle.
USMC photo

Lancer Combat Vehicle.

Inside Back Cover
The Ticonderoga-class USS Vincennes and aircraft carrier USS Kitty Hawk. U.S. Navy photo by Photographer's Mate 2nd Class William H. Ramsey

Back Cover
Advanced Amphibious Assault Vehicle.
USMC Photo

USS Dwight D. Eisenhower. U.S. Navy photo

Nuclear-powered sub PCU Virginia. U.S. Navy photo by General Dynamics Electric Boat